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MISSILE COMPONENT REPAIR WHILE WEARING NBC PROTECTIVE CLOTHING

John D. Waugh
Patricia W. Kilduff

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U. S. ARMY HUMAN ENGINEERING LABORATORY
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At the request of and with the assistance of the US Army Missile and Munitions Center and School, the US Army Human Engineering Laboratory assessed possible degradation in the performance of missile repair persons while wearing NBC protective clothing. Nine male soldiers, just graduated from the Advanced Individual Training Course in Missile Repair, were required to perform repair tasks in three replications. Two repair tasks were chosen; one considered non-difficult whose activities

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concentrated on procedural diagnostics and fault isolation; the second considered difficult, required manipulating small machine parts and hand tools requiring fine eye-hand coordination. The repair tasks were performed on the TOW and Dragon missile systems respectively with participants attired in duty (fatigue) uniform; protective mask and hood alone; protective gloves alone; and full Mission Oriented Protective Posture level 4 (MOPP 4) protective ensemble. Time to complete the repair task trials was the primary criterion measure.

The experimental results and subsequent comparative statistical analysis showed no degradation in performance of the easier procedures and diagnostic task. The time to complete the more difficult task was degraded (increased) on the average of 45% in MOPP 4 with a definite contribution to degradation attributed to the mask/hood and the protective gloves by themselves. A significant improvement attributed to learning from the first to the second presentation was found, but not from the second to the third presentation. The participants' degree of learning was neither enhanced nor held back while in protective clothing as compared to working in the duty uniform.

The level of physical activity while performing repair tasks was considered light work which is low risk in terms of body heat production. Even so, the participants experienced difficulty and discomfort to a large degree while performing which probably contributed to the degradation.

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APPROVED: ______________________
JOHN D. WEISZ
Director
US Army Human Engineering Laboratory

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US ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005

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The US Army Missile and Munitions School:

LTC James Porter, DCD
CPT Michael C. Kilgore, DCD
SFC Peter E. Cox, DCD

The US Army Missile Command:

Mr. Richard E. Harris, Missile Logistics Center

The US Army Chemical Center and School:

Mr. J. M. Cress, DCD

Armament Systems Inc. (on contract to HEL):

Mr. D. J. Shearin
Mr. David A. Yensan

US Army Human Engineering Laboratory:

Mr. Richard S. Camden

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TABLES

MISSILE COMPONENT REPAIR WHILE WEARING NBC PROTECTIVE CLOTHING

INTRODUCTION

The US Army Centers and Schools, under the command of Headquarters, Training and Doctrine Command (TRADOC), have been directed to prepare a Mission Area Analysis (MAA) in each of 12 mission areas in which the various centers and schools have responsibility. "The purpose of these MAAs is first, to assess the Army's ability to perform missions with existing programmed resources. Following the assessment, MAAs cite determined deficiencies and propose prioritized corrective actions in the areas of doctrine, training, force design and materiel." (4).

One such mission area, Combat Service Support (CSS), is the partial responsibility of the US Army Missile and Munitions Center and School (MMCS), Redstone Arsenal, AL. The mission of the Combat Service Support Directorate (CSSD), US Army Human Engineering Laboratory, is aligned with this same mission area, hence a collaboration for this experiment was established. The Combat Service Support Mission Area is supposed to address efforts directly related to the Army's capabilities to provide tactical commanders with, among other things, supply, maintenance, and services.

BACKGROUND

It is the responsibility of MMCS to address the CSS Mission Area with respect to both missile and ammunition systems. One of the major issues requiring evaluation by MMCS is the effect of a chemical attack on these systems, especially missile systems.

The question, discussed with the CSSD at HEL, was twofold. First, to what extent are the missile systems in the inventory vulnerable to chemical contamination, and if a missile system is contaminated, how survivable are its electronic components to chemical decontaminants? Second, if a missile system has been contaminated, what extra measures in terms of doctrine, training, personnel, and equipment will be required in order to render an adequate level of combat service support, particularly maintenance? The HEL was able to assist in answering the first part of the question via a research task placed with Armament Systems Inc. under contract to HEL. The report of findings is listed as Reference 8. The latter portion of the question, and the subject of this report, is basically whether missile system repair services are degraded if the components are contaminated and must be repaired by personnel in NBC protective clothing and equipment.

According to Reference 8, the performance of a missile system that has been exposed to chemical agents is not likely to be degraded, and can be deployed by adequately protected unit personnel. The problem arises if that system requires maintenance or repair while contaminated. Obviously,

a dedicated maintenance and repair facility will be required under these circumstances, with tools, workspace, and test equipment that can be readily decontaminated, or in the case of test equipment, be protected against contamination yet easily employed. Repair persons assigned the duty of repairing contaminated systems and components will be expected to be dressed in the highest level Mission Oriented Protective Posture (MOPP 4) attire. The attire and levels of protective posture are summarized in Table 1. The levels are generally associated with the degree of alert or probabilities of chemical attack, with level 4 being the all-up condition when personnel are physically in a chemical environment.

TABLE 1

Definition of Mopp Levels

	Protective Clothing and Equipment			
MOPP	Overgarment	Overboots	Mask/Hood	Gloves
1	Worn open or closed based on temperature	Carried	Carried	Carried
2	Worn open or closed based on temperature	Worn	Carried	Carried
3	Worn open or closed based on temperature	Worn	Worn hood open or closed based on temperature	Carried
4	Worn closed	Worn	Worn hood closed	Worn
Base-line	Not worn	Not worn	Not worn	Not worn

Degradation in the performance of duties by troops in MOPP is expected. Rakaczky (7) mentions five contributing factors responsible for the degradation, of which heat stress, he reports, is the only one to be investigated in depth. As a result of the preliminary efforts leading to the experiment reported here, a number six factor is identified and added. This factor resembles factor number three but is related to materiel and equipment design practice more than MOPP. These factors, not necessarily quoting Rakaczky, are as follows:

1. Body heat buildup or heat stress caused by the weight and bulk of the attire and its characteristics as an insulator (does not breathe) to an NBC environment.

2. Respiratory stress caused by the resistance to breathing caused by the filter and check valves of a protective mask.

3. Reduced limb and manual dexterity caused by the bulk and stiffness of the overgarments, gloves, and overboots.

4. Reduced visual and hearing performance caused by the protective mask and hood.

5. Stress caused by physiological and psychological discomforts, such as temperature, sweating, claustrophobia, restrictions to movement, etc.

6. The physical interferences caused by MOPP attire (and perhaps arctic clothing as well) can both degrade and prevent the accomplishment of certain tasks that are entirely possible in normal duty uniforms.

Discussions held with senior instructors at the MMCS during the planning of this experiment revealed that there were a number of missile repair tasks they found that were physically very difficult to impossible to accomplish because of interferences between the MOPP overgarment and gloves and the various enclosures, access openings, etc., typically encountered in missile systems. The design of these systems did not take into account personnel in MOPP.

It was the purpose of the experiment to determine if repair persons attired in MOPP 4, mask and hood only, or gloves only, experienced a degradation in performing representative repair tasks with respect to performing them in the duty (fatigue) uniform. The representative tasks chosen were, therefore, outside the realm of factor six above. The degradation in performance of the repair tasks was assumed to be primarily caused by lessening of visual, tactile, and manipulative capabilities as in factors three or four, with little or no contributions from heat stress phenomena, as in factor one. The repair tasks and testing environment were selected to minimize the heat stress factor. Later in the report, however, it will be noted that heat stress could not be entirely discounted. The types of stress listed in factors two and five could also contribute to performance degradation in this experiment.

METHOD

Participants

A total of 12 enlisted individuals (11 males, 1 female) were selected to participate in the experiment. They had graduated from the Advanced Individual Training (AIT) course for maintenance of TOW/Dragon (MOS 27E) missile systems 2 days prior to the initiation of the experimental trials. They ranged in age from 18 to 25, with all but three under 22 years of age. Their rank was E-1 to E-3, predominantly E-2, with length of service from 7 to 38 months with all but three serving a year or less. Two of the 12

were considered alternates. For personal reasons not connected with the experiment, the one female participant had to drop out late in the trials. At that point it was too late to administer a full set of trials to one of the alternates. All participants signed a volunteer consent form (Appendix A).

Support Personnel

Six senior instructors (five E-7's and one E-6) from MMCS served in the experiment as test proctors, monitoring the repair task trials for adherence to the repair manuals and quality of workmanship. They were additionally responsible for recording ambient temperatures during the trials, times to complete the trials, and qualitative observations of the participant's efforts and behavior in the trials.

As a precaution against the possible occurrence of heat stress or heat injury, a request for medical personnel to be detailed to the site of the experiment was forwarded to the post hospital. Because of personnel shortages the request was denied; however, prior to the start of the experiment the proctors and experimenters were provided a 2-hour orientation on the subject of heat stress, how to spot it, and first-aid treatment techniques.

Apparatus/Facilities

Two nearly identical test stations and a day room were provided by the Missile Logistics Center of the US Army Missile Command. Each station had approximately 150 square feet of partitioned floor space with two standard GSA electrical work benches. The building containing these facilities constituted an environment of fairly constant temperature, few distractions, and isolation from other activities. Each test station was equipped with a complete tool kit normally issued to missile repair personnel in the field, including assortments of wrenches, pliers, screw drivers, soldering equipment, etc. Also provided were portable, solid state digital multimeters and oscilloscopes, with an assortment of test probes and clip-leads.

Each test station was equipped with an M-151E2 TOW missile system including launch tube, tripod, traversing unit, optical sight, missile guidance set (mounted in a repair facility test stand), and a charged battery pack. Both a TOW system peculiar breakout box (to provide circuit test points and test function switches) and a firing circuit test box were provided as normal for a TOW system repair facility.

Each test station was provided with an AN/TAS-5 night sight for the M47 Dragon missile system. These sights were unserviceable for field use and were provided by the MMCS from training stocks used to teach disassembly procedures. The repair tasks of the experiment centered around these two systems.

The following repair manuals were provided for the above missile systems:

TM 9-1425-472-12 TOW Self Test
TM 9-1455-472-34-1 TOW Repair
TM 9-1425-484-24 Dragon Night Sight Repair

Environmental temperatures were measured with a Reuter-Stokes Canada, Ltd. Model R55-2110 heat stress monitor consisting of dry bulb, wet bulb, and globe temperature sensors inputting to an electronic digital display. Dry bulb, wet bulb, and Wet Bulb-Globe Temperature index (indoor) in Fahrenheit degrees were recorded for each experimental trial.

Other apparatus used during the course of the experiment were two ordinary 60 minute mechanical stopwatches, a Baush & Lomb Ortho-Rater Cat. No. 71-21-30-02 vision tester, and the Crawford Small Parts Dexterity Test; a copyrighted test to measure fine eye-hand coordination.

The following protective items (sized to fit where appropriate) were issued to each participant in the experiment:

Bag
Overgarment
Overboots
Mask/Hood
Gloves with liners

A complete list of protective clothing and equipment may be found in Appendix B.

Procedure

The MMCS selected the TOW and Dragon systems as representative of equipment for which they sought information. Maintenance of these two systems is taught simultaneously in the Advanced Individual Training course from which the participants had just graduated. Two repair tasks were selected by senior MMCS cadre closely associated with the systems. One task to be selected was to be characterized as "easy" and the other to be characterized as "difficult," as judged by the cadre members, in terms of time consumption, requirements for accuracy, and fine eye-hand coordination and manipulation. The tasks chosen also had to be demonstrated as not physically impossible to perform while fully attired in MOPP level 4.

The easy task selected was to perform the TOW self-test routine. The participant was required to isolate, verify, remove, and replace a faulty circuit board (a contact insulated with masking tape), verify the operation of the replacement circuit board, complete the test routine, and remove and replace by soldering a 2-inch jumper wire across terminal posts. The difficult task selected was to remove and replace a motor driven nutating mirror assembly deep in the tracker portion of a Dragon system night sight. This task required the use of a variety of hand tools, including a 14-inch shaft Phillips screwdriver, a prong type spanner, snap-ring pliers, etc. Both of these routines were fully covered in the repair manuals provided.

The skills required in performing the easy (TOW) repair task were primarily knob and switch actuation, as well as reading analog and digital meters and oscilloscope patterns. Manual dexterity and eye-hand coordination were required to a lesser degree in removal and replacement of the circuit board (two screws), and in replacing the soldered jumper wire. Reading and following the directions in the repair manuals was required in both repair tasks and enforced by the NCO proctors. The skills primarily in evidence during the difficult (Dragon) task were fine eye-hand coordination and dexterity in the manipulation of small screws, snap-rings, and careful withdrawal and insertion of the assembly without marring the surface of the nutating mirror.

After each trial, the participants were asked to critique themselves in that trial (see Questionnaire, Appendix C).

Each participant, when performing an assigned repair task, would be attired in one of the four conditions: 1) duty (fatigue) uniform; 2) duty uniform with protective mask and hood; 3) duty uniform and protective gloves, with cotton liners; 4) full MOPP level 4 apparel. The participants had a 30-minute period of acclimatization with no activity just prior to performing repair tasks in the mask/hood and MOPP 4 treatments.

Each participant performed both the easy (TOW) and the difficult (Dragon) repair tasks under each of the four conditions of attire listed above.

Each participant performed repair tasks under each combination of attire and task difficulty a total of three times. Each combination of attire and task difficulty was exhausted before the whole sequence was repeated; likewise for the final repetition. The order of presentation of the condition and task combinations administered to the participants was randomized except that no one participant was administered successive or back-to-back trials. When not engaged in performing repair tasks, the participants were used as assistant instructors in the AIT course from which they had just graduated. Scheduled participants were bussed from the school area to the experimental facility; a distance of approximately 2 miles. Each participant was issued a copy of the schedule so that he/she knew when their trials would occur, and what combination of attire and task would be administered. Their MOPP equipment was stored in each participant's equipment bag in the day room located adjacent to the test stations. They donned MOPP gear and acclimatized in the day room.

The participants were tested two at a time; one in each test station. An NCO proctor remained with each participant throughout the trial. The proctors were utilized two at a time on a daily rotation schedule. They performed their normal duties at MMCS when not on duty with the experiment.

Experimental Design

The experimental trials were organized as a pair of two-way designs with replication. One of the designs dealt with the easy (TOW) repair tasks only while the other design was for the difficult (Dragon) task only. The pair of designs were identical in form in terms of conditions (uniform and MOPP) and replications (three each). Trials in each task category were intermixed in random order, and all participants were administered all combinations making the designs complete. Within each of the three replications, the order of presentation of the conditions was randomized.

In terms of testing hypotheses, the trial cells in each repair task category were arranged to form a conditions x subjects design, and a conditions x levels design (5). The conditions x subjects arrangement allows testing of the null hypotheses for uniforms/MOPP combinations, and participants combining all three replications. The condition x levels (replications are equated levels) arrangement allows testing of null hypotheses of uniform/MOPP combinations within each replication, and the effect of the replications themselves. There was no practical basis for comparing the easy (TOW) repair task to the difficult (Dragon) repair task because they were generally unrelated with respect to the system assemblies, type of repair routine, and kinds of manipulations involved.

RESULTS AND ANALYSIS OF RESULTS

Figures 1 through 10 illustrate the participants performing their repair tasks during various trials.

For purposes of analysis, the trials were organized into a 9 x 4 x 2 x 3 matrix. Nine male[1] participants were exposed to each of three independent variables in a randomized fashion. The independent variables were four conditions, two repair tasks, and three replications or presentations. The levels for each of these independent variables is shown in Table 2. The dependent variable was the total time to complete a task. For this experiment, specific measures of error were not recorded, although, both test participants and proctors <u>did</u> make comments about any problems participants may have encountered and errors made.

[1] One female participated in the study but, due to personal reasons, did not complete it. A test of confidence intervals was performed on her data (mean time to complete a task for each condition). This test showed her to be within the other participants' .95 confidence interval for seven out of eight means generated, and superior for the remaining mean.

Figure 1. Test proctor emphasizing repair manual procedure - TOW repair task (duty uniform).

Figure 2. Connecting test equipment - TOW repair task (MOPP 4).

Figure 3. Performing self test using oscilloscope - TOW repair task (MOPP 4).

Figure 4. Soldering wire in missile guidance set chassis - TOW repair task (MOPP 4).

Figure 5. Addressing cover plate - Dragon ni; sight repair task (MOPP 4).

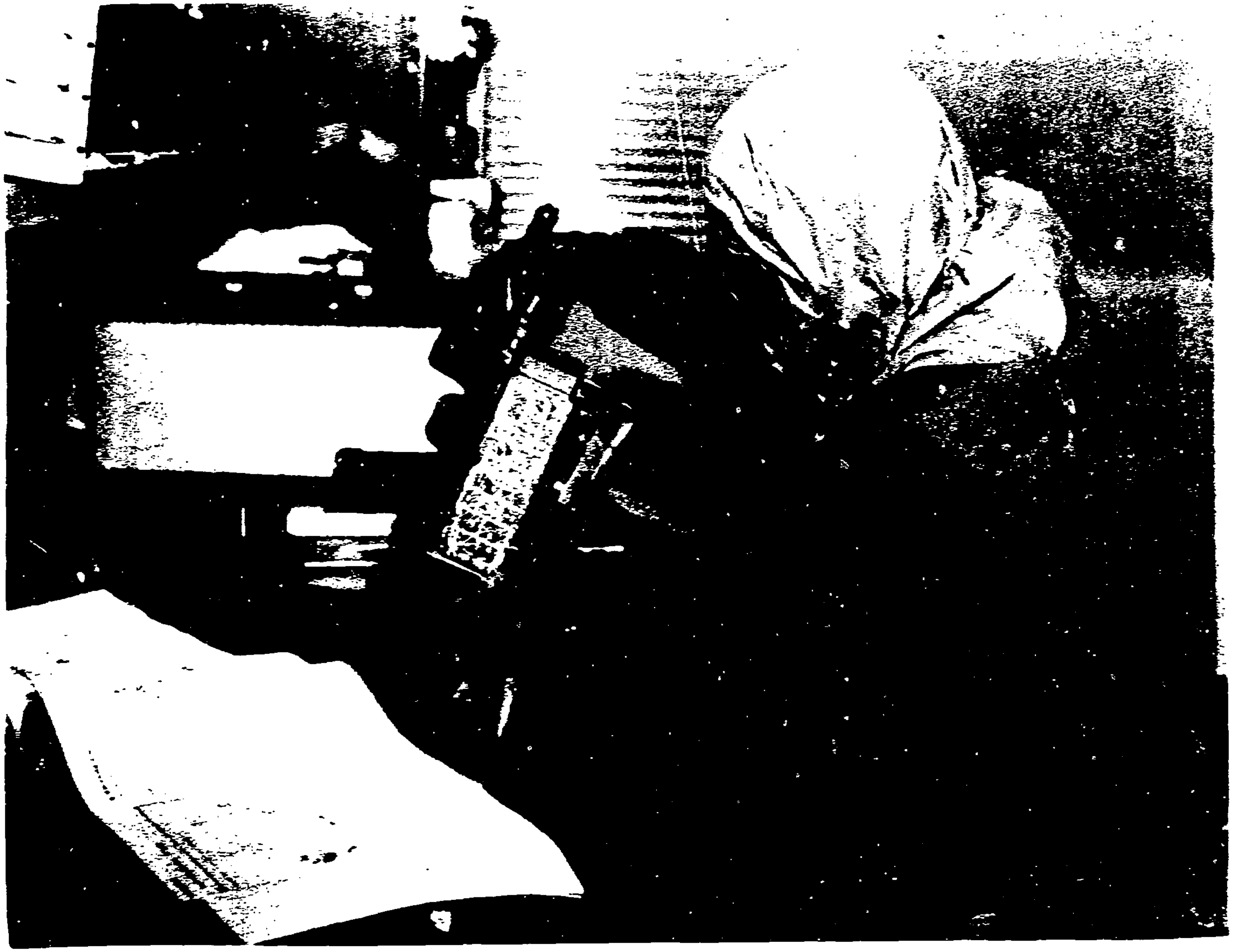


Figure 6. Cover plate removed exposing circuit card - Dragon repair task (MOPP 4).

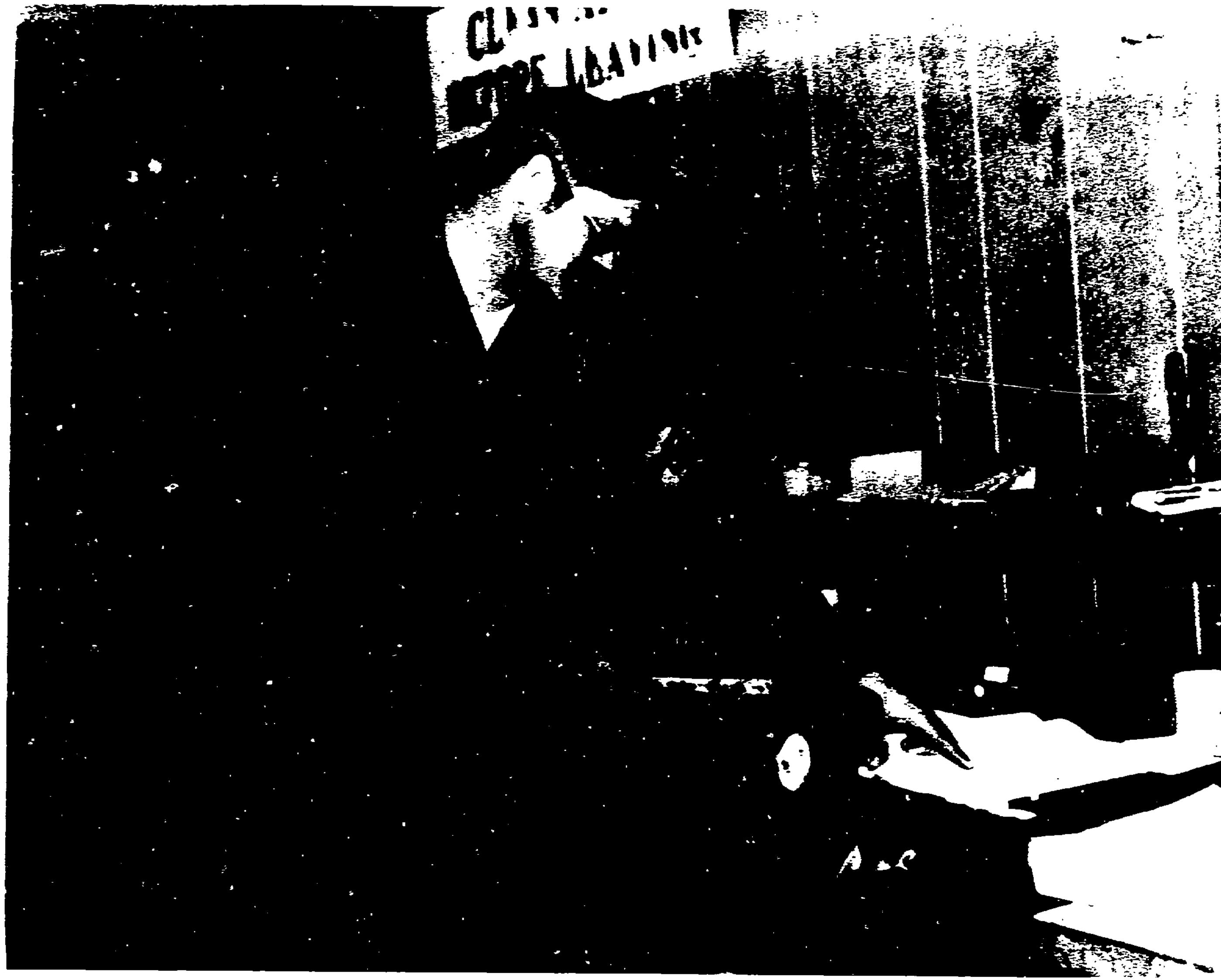


Figure 7. Test proctor emphasizing repair manual procedure - Dragon repair task (gloves only).

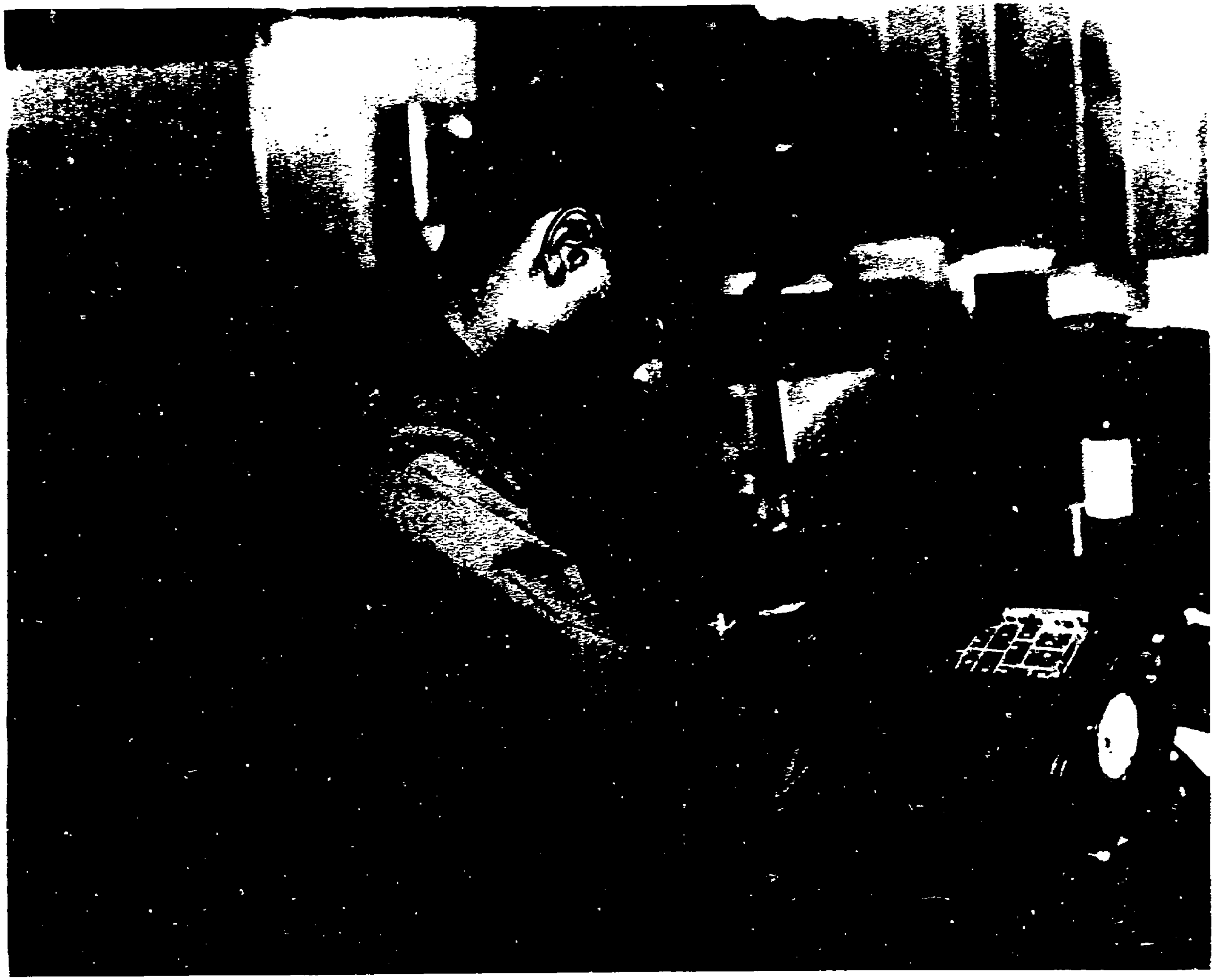


Figure 8. Removing circuit card holding screws - Dragon repair task (gloves only).

Figure 9. Using flashlight and 14-inch screwdriver on mutator assembly holding screws - Dragon repair task (MOPP 4).

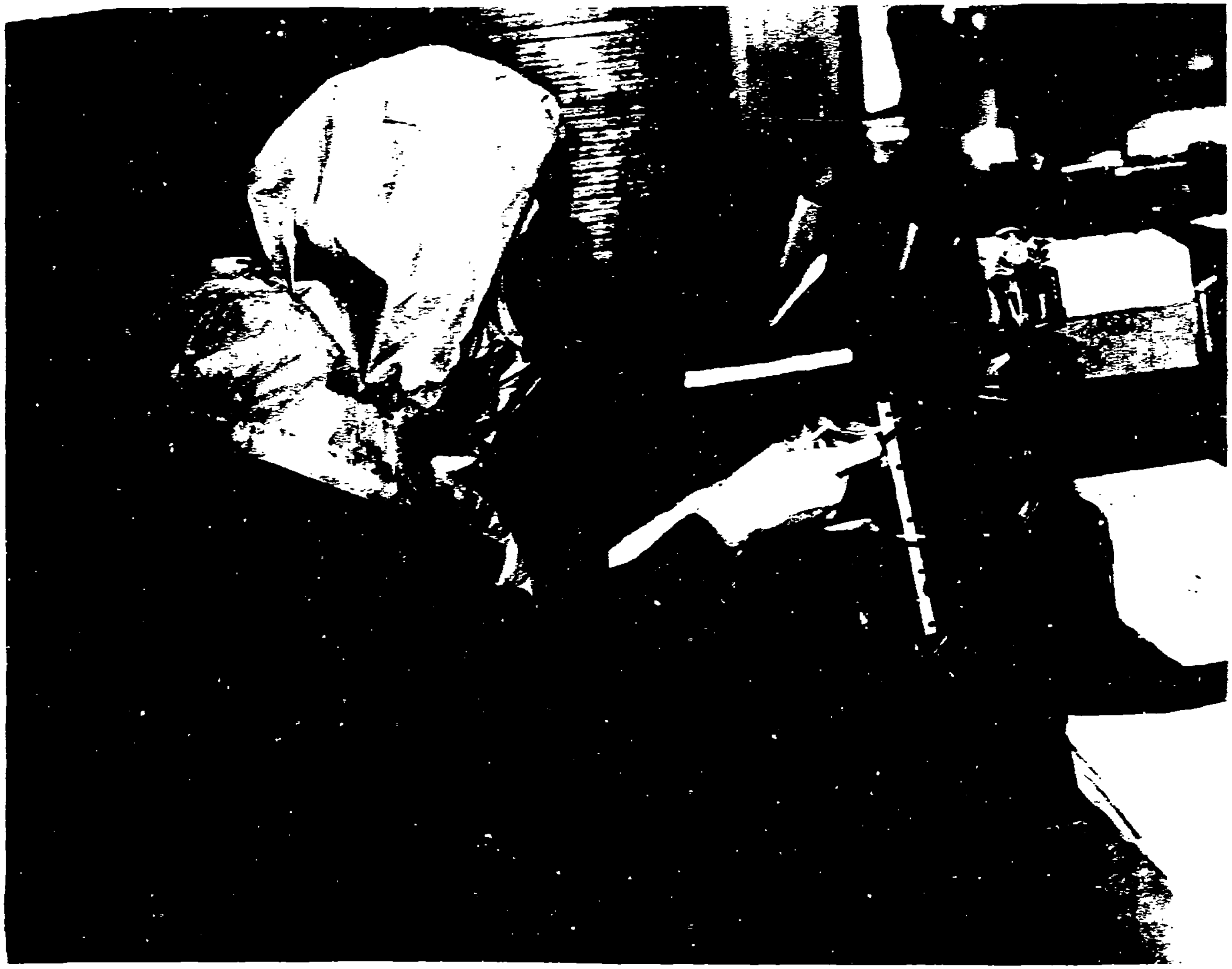


Figure 10. Disconnecting nutator assembly umbilical - Dragon repair task (mask/hood only).

TABLE 2

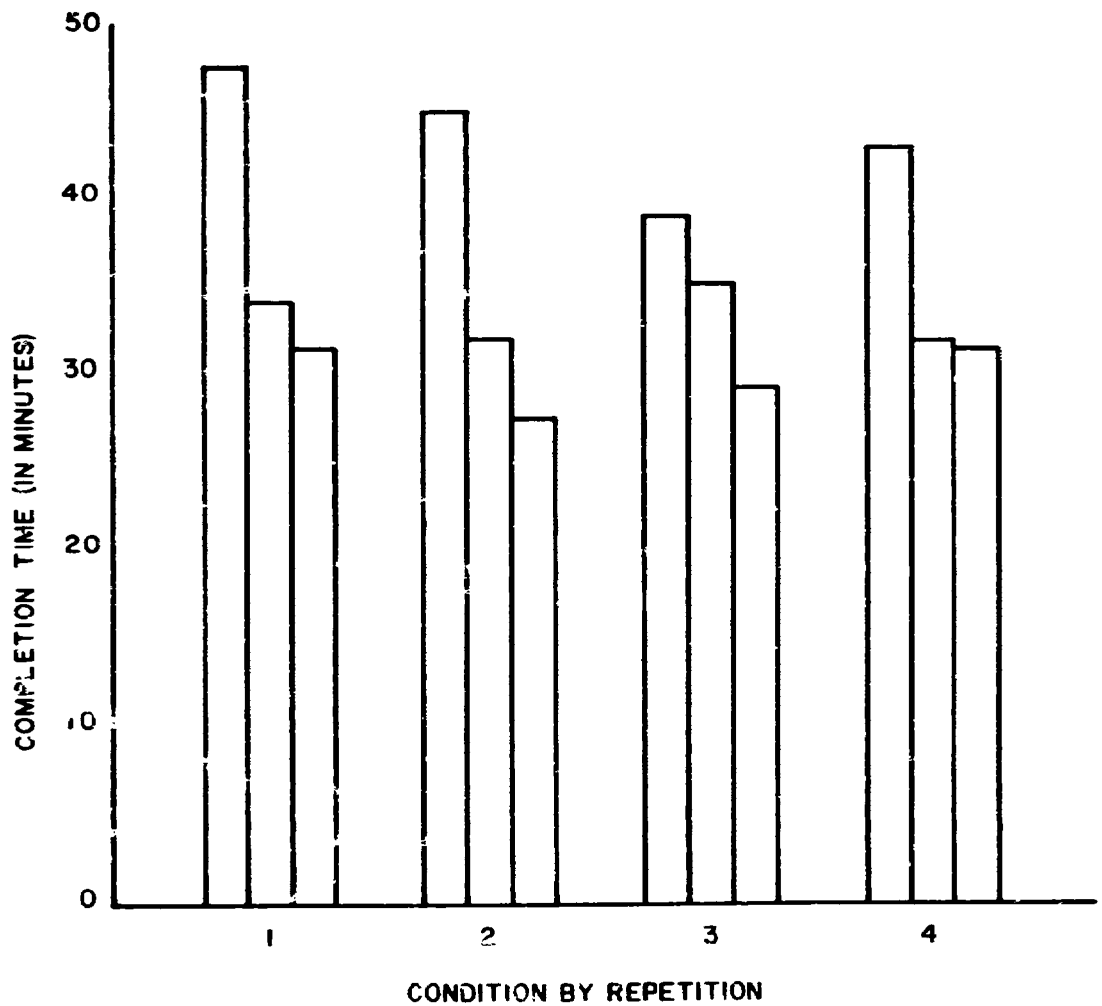
Levels of Independent Variables

Independent Variables	Levels
Condition	1. Duty uniform only
	2. Duty uniform and mask/hood
	3. Duty uniform and gloves
	4. Full MOPP gear
Repetitions	1. First presentation
	2. Second presentation
	3. Third presentation
Task	1. TOW self test (easy)
	2. Dragon night sight (difficult)

Mean trial times to complete repair tasks were computed. Figures 11 and 12 show the mean times across conditions and repetition for Task 1 and Task 2 respectively. The mean times of Task 1 show a decrease in times across repetitions, but not necessarily across conditions. There is a decrease in time for Conditions 1, 2, and 3, and, an increase for Condition 4.

The mean times of Task 2 show a steady increase in time by condition and a decrease in time by repetition for all but Presentations 2 and 3 for Condition 1. The actual numbers for the mean and also the standard deviation are shown in the legends for Figures 11 and 12. Figure 13 shows the mean time per treatment, regardless of the repetition.

The method of analysis was both a three-way (condition, repetition, task) and a two-way (condition and repetition by task) analysis of variance (ANOVA) computed through the Statistical Package for the Social Sciences (SPSS) (6) on the Ballistic Research Laboratory Cyber 76 computer. The post hoc test used to identify contrasts between levels of independent variables was Duncan's Multiple Range Test (2). A dependent t-test was also performed. Based on subjective opinion, a frequency distribution of problem tools used during each task is included. The results of these tests are shown in the following summary tables and fully mounted in the DISCUSSION section.



CONDITION 1

$\overline{X}$	47.4	34	31.5
s	12.04	7.73	8.71

CONDITION 2

$\overline{X}$	44.9	31.8	27.4
s	10.32	6.83	4.99

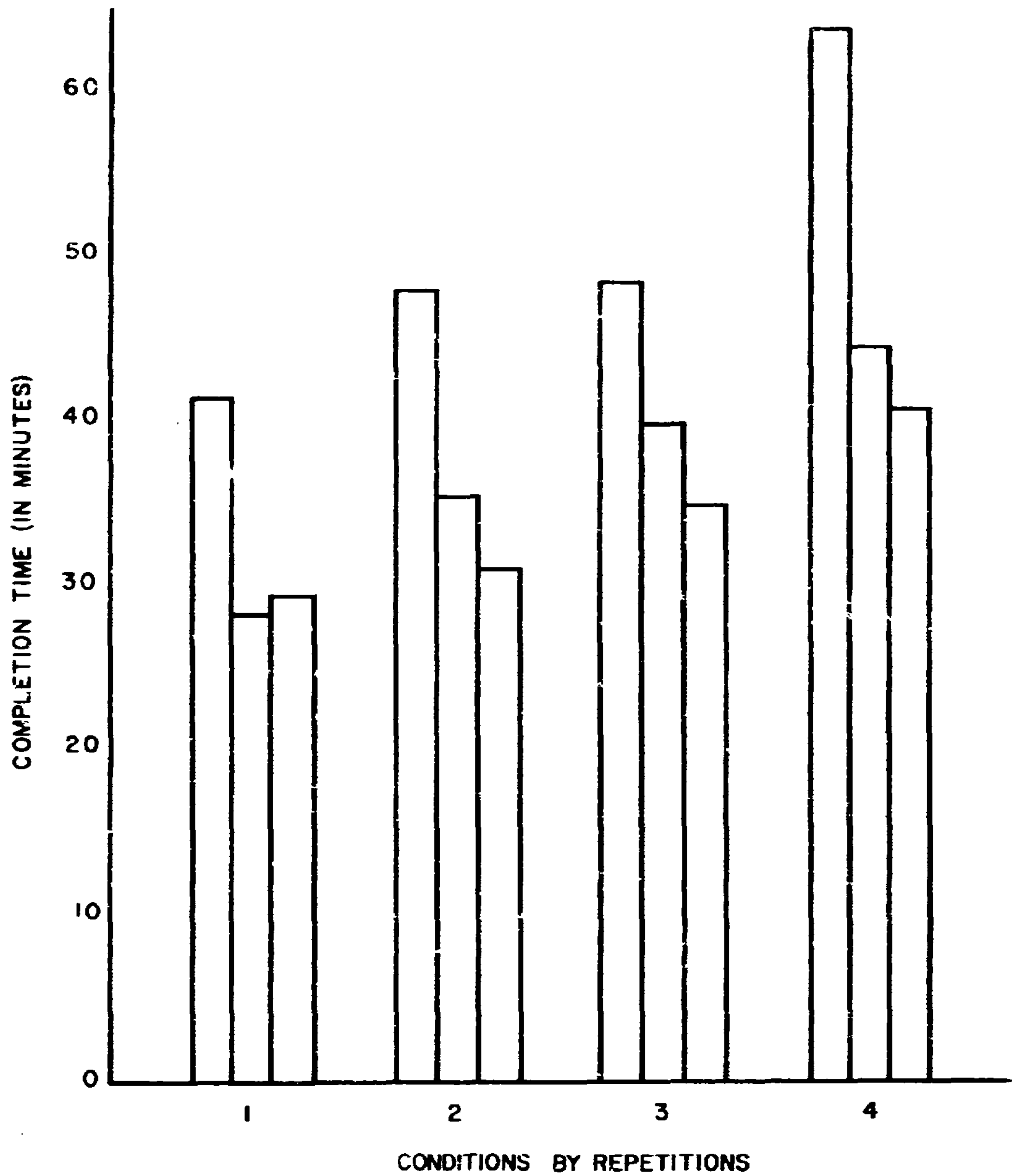
CONDITION 3

$\overline{X}$	38.8	35.1	29.1
s	12.49	5.99	7.13

CONDITION 4

$\overline{X}$	42.9	31.7	31.3
s	11.98	6.6	10.3

Figure 11. Mean time to completion - Task 1 (TOW).



CONDITION 1

$\overline{X}$	41.3	28.3	29.1
s	10.56	4.83	7.75

CONDITION 2

$\overline{X}$	47.9	35.2	31
s	10.84	8.8	9.52

CONDITION 3

$\overline{X}$	48.4	39.6	34.6
s	14.09	6.31	7.37

CONDITION 4

$\overline{X}$	63.1	44.2	40.4
s	24.36	11.4	6.96

Figure 12. Mean time to completion - Task 2 (Dragon).

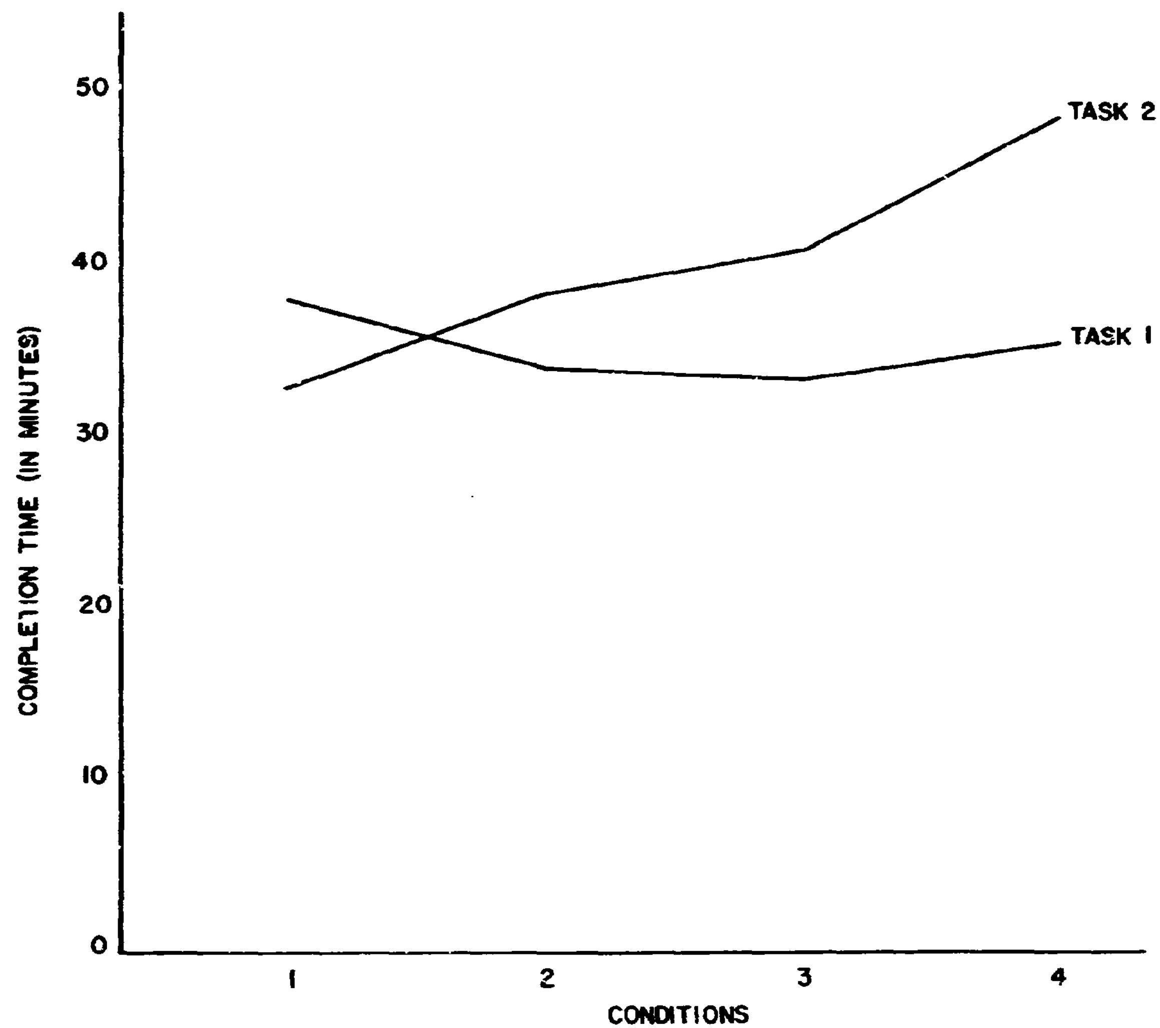


Figure 13. Mean times to completion - Task 1 (TOW) and Task 2 (Dragon).

Table 3 is the data from the three-way ANOVA. Significant main effects are shown for all three independent variables, with condition p<.05, repetition, p<.001, and task, p<.05. There is no practical basis for comparing Task 1 to Task 2 because they were generally unrelated with respect to the system assemblies, type of repair routine, and kinds of manipulations involved. Further reference to task will be as either Task 1 (TOW self test) or Task 2 (Dragon night sight). A significant interaction effect is shown only for condition by task, p<.001. This is also immateriel because the tasks were not related.

TABLE 3

3-Way ANOVA (Condition x Repetition x Task)

Source of Variance	df	SS	MS	F	
Subjects	8	3397.82	424.73		
Condition (con)	3	1211.75	403.92	4.64	.05
Repetition (rep)	2	9296.29	4648.14	40.16	.001
Task	1	1199.45	1199.45	7.09	.05
Con x Rep	6	797.45	132.91	1.40	NS
Con x Task	3	2201.50	733.83	10.86	.001
Rep x Task	2	74.90	37.45	.34	NS
Con x Rep x Task	6	246.55	41.09	.46	NS

Table 4 shows the data from the two-way ANOVA broken down into Task 1 and Task 2. In Task 1, a significant main effect is shown only for repetitions, p<.001. The interaction between condition and repetition is not significant. In Task 2, significant main effects are shown for treatment, p<.05, and repetitions, also p<.05. The interaction is once again not significant.

Because the Tasks 2 (Dragon) cell sample standard deviations ranged from a low of 4.38 to a high of 24.63, nonhomogeneity of variance was indicated. A recommended logarithmic transformation (5, page 88) of the Task 2 data was applied, and a recalculation of the Task 2 ANOVA produced the same main and interaction effects results as appear in Table 4.

TABLE 4

2-Way ANOVA (Condition x Repetition)

Source of Variation	df	SS	MS	F	
Task 1					
Subject	8	1843.55	230.44	-	
Condition (Con)	3	160.06	53.35	.610	NS
Repetition (Rep)	2	3828.21	1914.10	30.95	.001
Con X Rep	6	406.59	67.76	.835	NS
Task 2					
Subject	8	2968.97	371.12	-	
Con	3	3212.98	1070.99	14.98	.001
Rep	2	5376.63	2688.31	16.38	.001
Con x Rep	6	608.28	101.38	.933	NS

Where more than two conditions or levels are examined in an ANOVA, a significant test statistic indicates that at least one mean is significantly different from at least one other mean. Further analysis is necessary to determine exactly which means may be different from the others, and which means may not be. Two statistical test routines were employed to complete the analysis.

The results of the Duncan Multiple Range Test (2) on the condition and repetition levels are as follows. For Task 1, the ANOVA revealed that none of the conditions were significantly contrasted from the others. For the repetitions, Presentation 1 was significantly contrasted from Presentations 2 and 3, both $p<.05$. The results of the Range Test on Task 2 data show that Conditions 1 and 4 are significantly contrasted not only with each other, but also with Conditions 2 and 3, all at the $p<.05$ level. In Task 2, Presentation 1 is significantly contrasted from both Presentations 2 and 3 at the $p<.05$ level.

Based on the Range test results, dependent t-tests were performed on the three repetitions of Conditions 1 and 4. Bonferroni t statistics (3) were used in order to split up the level of significance among the repetition comparisons. Task 1 shows Presentation 1 to be significantly different from Presentations 2 and 3 at the $p<.05$ level for both Conditions 1 and 4. The dependont t-test for Task 2 shows Presentation 1 to be significantly different from Presentations 2 and 3 for Task 1 and no significant differences between Presentations for Task 2. Table 5 illustrates the outcome of those two tests.

TABLE 5

Duncan Multiple Range Tests (2)

Task 1 (TOW)

Presentation	3rd	2nd	1st
Mean	30.19	32.83*	44.00

Task 2 (Dragon)

Condition	Duty Uniform	Mask/Hood	Gloves	Full MOPP
	1	2	3	4
Mean	33.63	38.70	40.37	48.85
Presentation		3rd	2nd	1st
Mean		33.58	37.33	50.25

Dependent t Tests

Task 1 (TOW), Condition 1 (Duty Uniform)

Presentation	3rd	2nd	1st
Mean	31.5	34.0	47.4

Task 1 (TOW), Condition 4 (Full MOPP)

Presentation	3rd	2nd	1st
Mean	31.3	31.7	42.9

Task 2 (Dragon) Condition 1 (Duty Uniform)

Presentation	3rd	2nd	1st
Mean	29.1	28.3	41.3

Task 2 (Dragon), Condition 4 (Full MOPP)

Presentation	3rd	2nd	1st
Mean	40.4	44.2	63.1

*Means underscored by the same line are not significantly different; means not underscored by the same line are significantly different.
(Duncan tests, $p<.05$, Dependent t tests, $p<.0167$)

Figures 14 and 15 show the frequency with which the participants complained of difficulty with specific tools for Tasks 1 and 2 respectively. The specific tools chosen for illustration, solder and desolder for Task 1, and spanner and snap ring pliers for Task 2, had the highest frequency of complaint.

Figure 16 is a plot of the mean time to task completion for the participants by trial number. Since the order of presentation of both task and treatment (attire) was randomized, the graph represents an aggregate of the experimental factors. There is a definite downward (improvement) trend within the first presentation.

DISCUSSION

In addition to being considered the easier of two tasks, the TOW self-test repair task was characterized as having fewer chores requiring fine eye-hand coordination in the manipulation of small parts and hand tools. It placed more emphasis on following procedure, knob and switch actuation, and the display reading and interpretation actions typical of diagnostic routines. The Dragon repair task was the approximate converse of the TOW task with no diagnostics and a host of operations manipulating small machine parts and a variety of hand tools. The statistical testing of the mean times to complete the TOW task showed no influence of the mask/hood, glove, or MOPP 4 conditions in degrading performance in the TOW repair task. Statistical testing of the mean times to complete the Dragon task, however, confirmed a performance degradation attributable to both the mask/hood and the gloves by themselves, and to an even greater extent, the MOPP 4 level attire. Further, since there was no significant difference between the mask/hood only and gloves only trial means, these items apparently contribute equally to the overall degradation observed in the MOPP 4 trials. Specifically, the MOPP 4 trials in the Dragon repair task took 45.3 percent longer to accomplish than in the duty uniform while the mask/hood only and gloves only trials took an average of 17.6 percent longer.

A significant improvement in the time to complete the repair tasks from the first to the second presentations was noted. Further, statistical tests showed that an improvement with repetition was still in evidence between the first and second presentation for the duty uniform treatment alone, and for the MOPP 4 treatment alone. In no instance was there a significant difference between second and third presentations. Though not considered meaningful, therefore not specifically tested, the statement probably holds for the mask/hood only and gloves only treatments as well. Table 6 lists the percentage of improvement in task completion times for the duty uniform and MOPP 4 treatments by repair tasks derived from the means appearing in Figures 11 and 12.

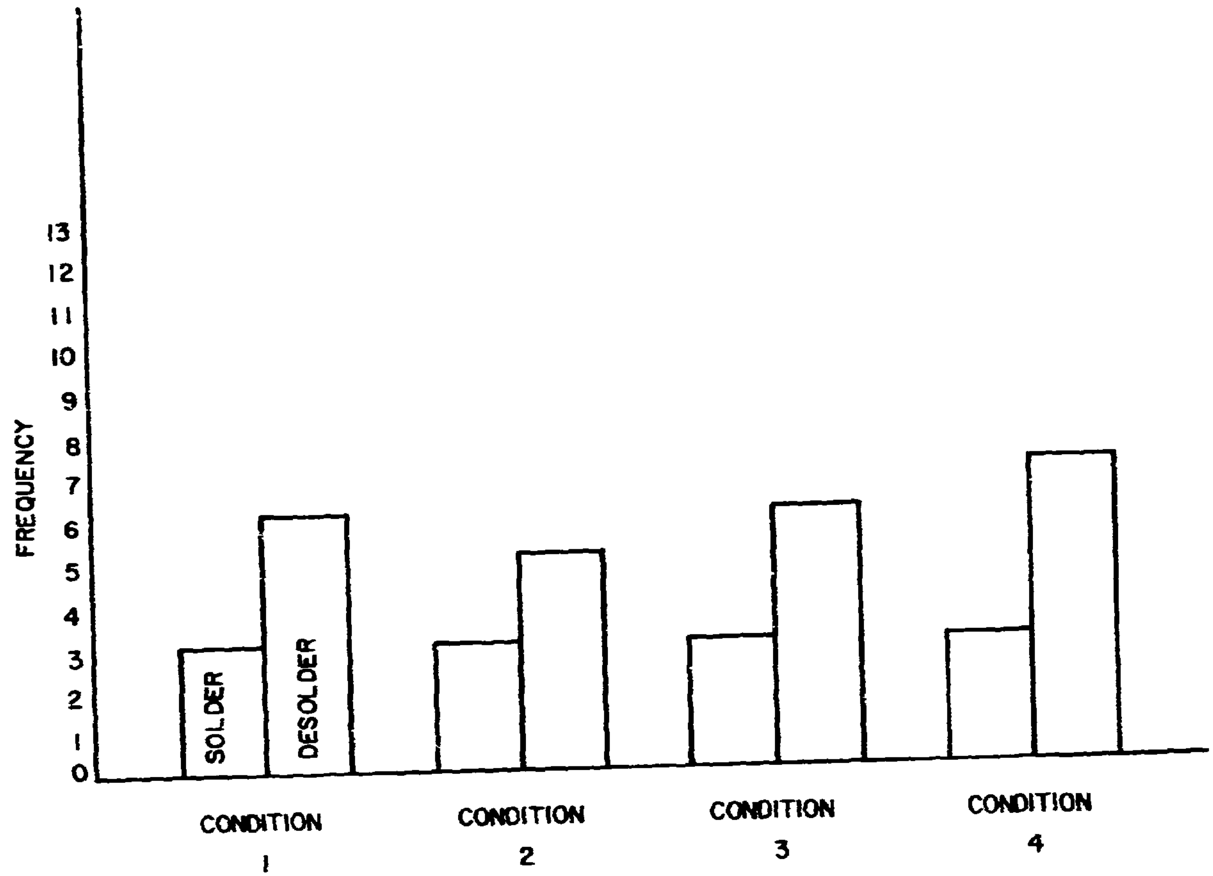


Figure 14. Tool difficulty frequency - Task 1 (TOW).

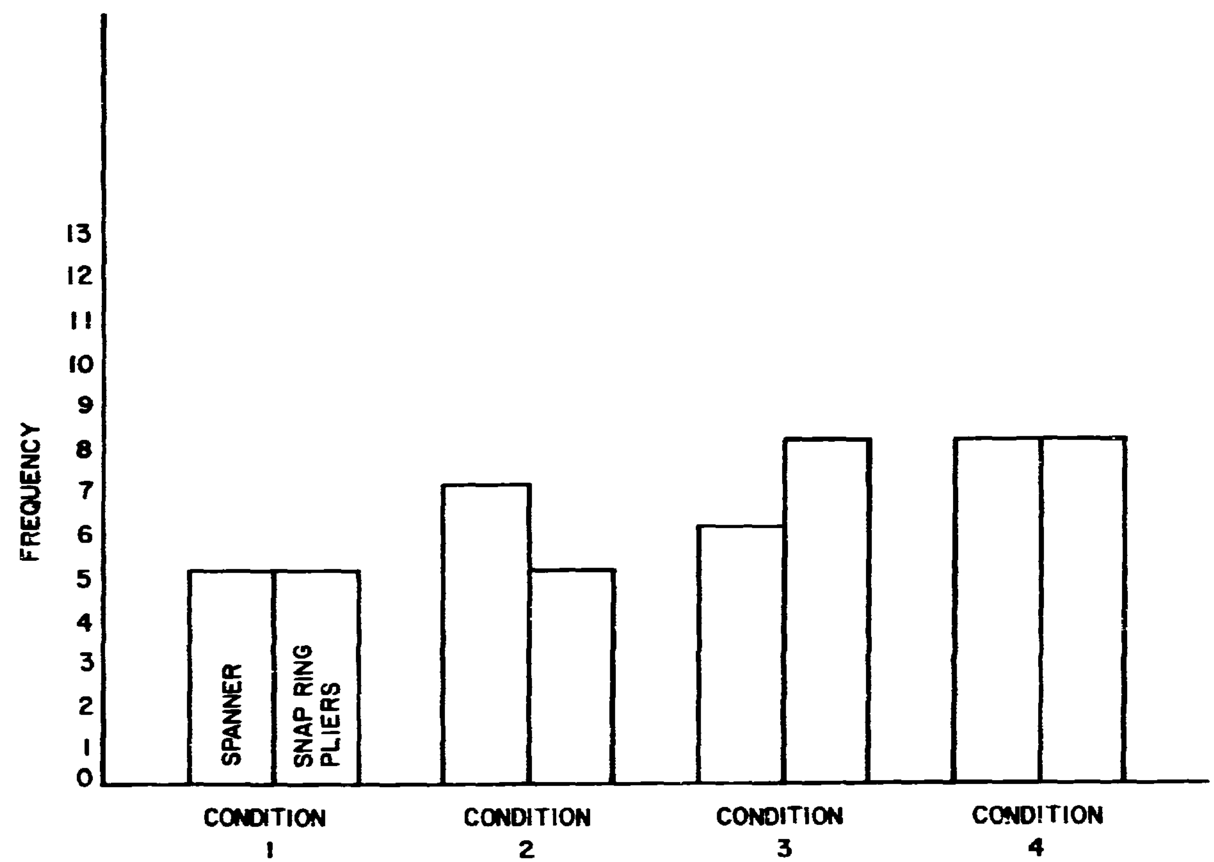


Figure 15. Tool difficulty frequency - Task 2 (Dragon).

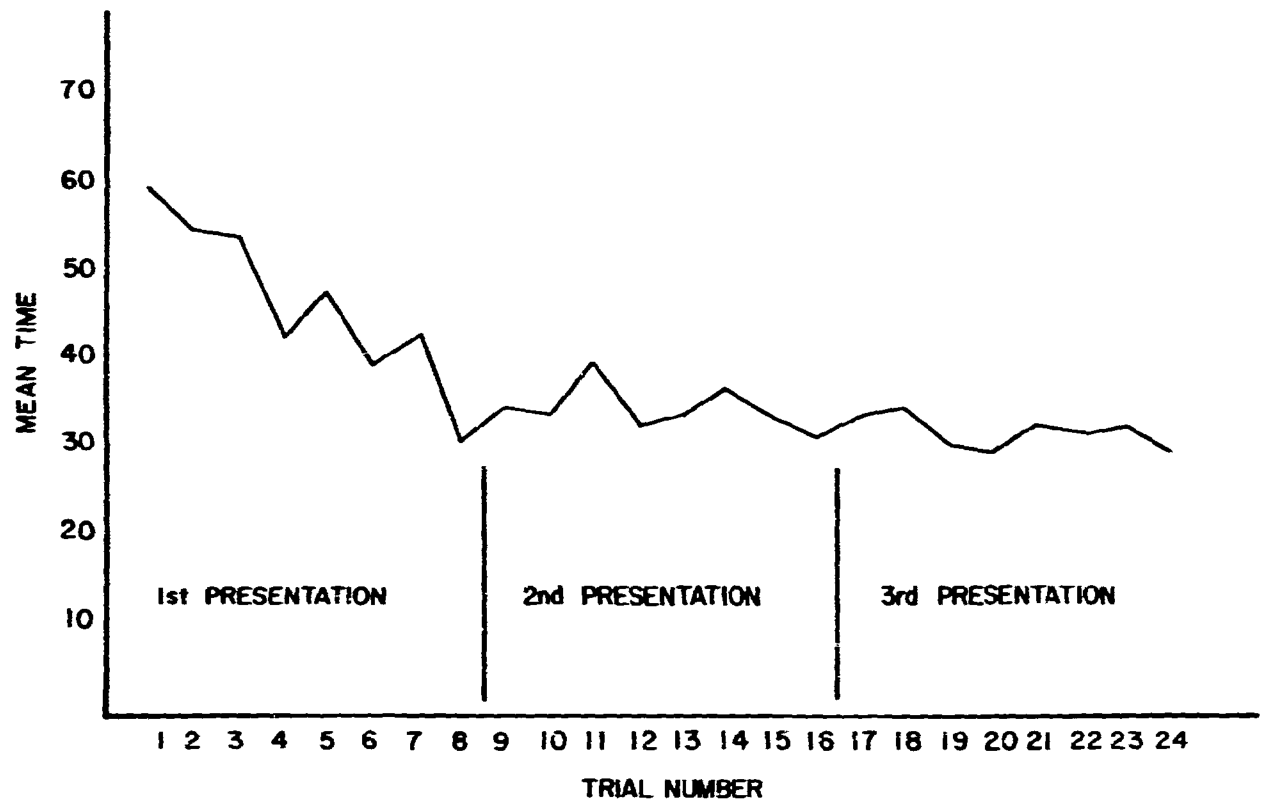


Figure 16. Mean times to completion - task and condition randomly presented.

TABLE 6

Percent Improvement in Mean Times From Presentation 1 to Presentation 2*

	Duty Uniform	MOPP 4
Tow-Self Test	39.4	35.3
Dragon-Night Sight	45.9	38.7

* All significant, $p<.05$.

However, for each of the three presentations, which are replications of the experiment, each participant was exposed to four trials corresponding to the four conditions (duty uniform through MOPP 4, in random presentation), in each repair task category. It may be concluded that some learning occurred as was evidenced by the improved times between the first and second presentations. It, then, must be assumed that learning occurred within at least the first presentation, transferred across the conditions. The assumption is supported by the plot in Figure 16 which exhibits a downward trend within the first eight trials. While the participants were fresh from the classroom where they had hands on experience with repairing the equipment, there existed a definite impression that they did not have as much experience in following the specific routines item by item as they appear in the manuals. Learning to do the repair routines " by the book" in repeated trials may account for some of the initial reduction in the mean times to complete the repair tasks.

The analyses of variance performed on the means in each repair task category did not yield a significant F statistic for interaction between the condition (attire) factor and the replication factor. The absence of an observed interaction means that either factor when presented alone may change the population mean by a different but constant amount. When both factors are present, the population mean is changed by an amount equal to the sum of effects of each factor; hence, the effects of two factors are said to be additive (9). In this experiment the interpretation is that the attire worn by the participants had no differential effect on the degree of improvement (learning) observed in the repeated presentation of the repair tasks. In more specific terms, the participants exposure to repair tasks while attired in the MOPP 4 neither enhanced nor degraded the learning that occurred in relation to the learning that occurred while in the duty uniform or the mask/hood only and gloves only conditions for that matter.

Having had all of the participants exposed to all of the condition/-task combinations in a randomized order of presentation prevents performing a more specific examination of the learning factors involved. It may be suggested, however, that the observed improvement under the duty uniform condition could be accommodation to the repair routine; while the observed improvement in the MOPP 4 treatment could reflect the participants becoming accommodated to the MOPP attire. Referring back to Figure 12, not

only was there a general improvement in task completion times in each of the conditions when the tasks were repeated, but there was also a trend toward reduced variability (standard deviation) from the first presentations of tasks to the two repetitions that followed. This would suggest a settling down or accommodation to the repair routine and/or the wearing of MOPP attire on the part of the participants.

The participants while performing their repair tasks sat at a bench, or on the floor, making moderate arm movements. According to TB MED 507 (1), this activity constitutes "light work" in terms of metabolic heat production which is the lowest risk category with respect to heat injury. The participants performed their tasks at temperatures ranging from 65°F to 84°F, mean 76°F, standard deviation 3.3; and WBGT ranging from 56°F to 77°F, mean 67°F, standard deviation 4.2°F. Each participant and test proctor were given post trial opportunities to comment on difficulties, problems encountered, etc. Table 7 lists a frequency count of the difficulties encountered during performance of repair tasks, culled from the collected comments, which may be related to the five Rakaczky reported factors discussed in the BACKGROUND section.

TABLE 7

Difficulties Observed During Performance of Repair Task While in MOPP 4 By Both Participants and Proctors (not related to task type or tools)

Reported Difficulty	Frequency
Repeated minor mistakes	12
Whole body heat buildup, fluid loss (perspiration)	10
Nervousness and frustration	8
Tendency to hurry, rush task completion, carelessness	7
Difficulty breathing, breathing regulation	6
Perspiration inside mask	5
Fogging of mask lenses	4
Neck strain, stiffness, headache from close up viewing of work	3
Claustrophobic type reaction	2

Although there were no heat casualties, evidence of heat buildup and its associated discomforts and difficulties were positive. Figure 17 illustrates a participant's fatigue shirt soaked through with perspiration immediately following a trial in MOPP 4.

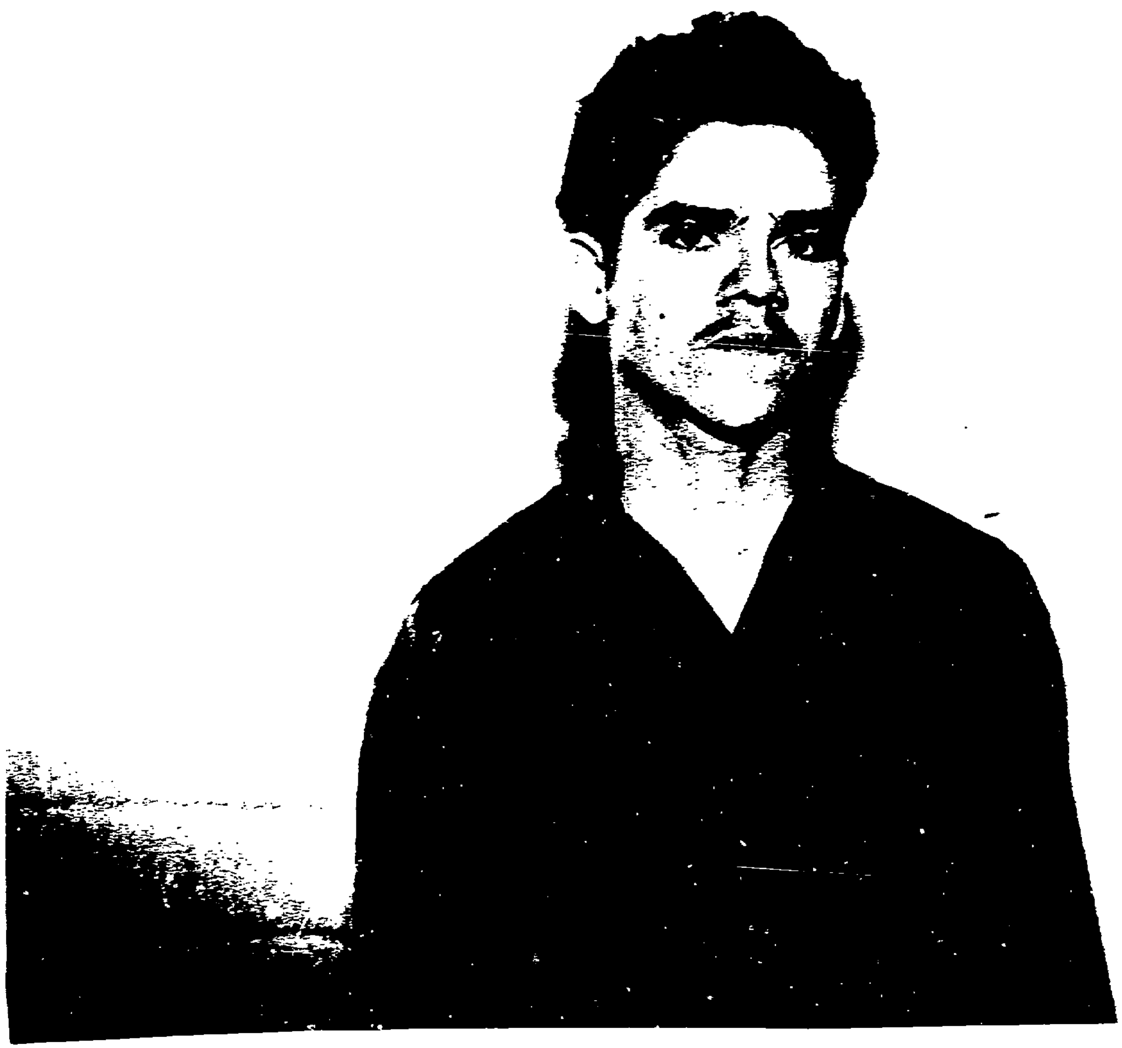


Figure 17. Fatigue shirt soaked with perspiration immediately following MOPP 4 trial.

CONCLUSIONS

1. Participants performing the TOW repair task, characterized as mainly procedures and diagnostics, turned in equal completion times regardless of the attire they were wearing.

2. Participants performing the TOW repair task significantly improved (decreased) their completion times between the first and second presentation of the trials, but not between the second and third presentation of the trials. This was true whether the participants were in the duty (fatigue) uniform or in MOPP 4.

3. Participants performing the Dragon repair task, characterized as manipulating small parts and hand tools requiring fine eye-hand coordination, accrued completion times that were degraded (increased) on the average of 45 percent in MOPP 4 compared to the duty uniform.

4. Participants performing the Dragon repair task while in the mask/hood only and gloves only conditions accumulated completion times which were equally degraded an average of 18 percent compared to the duty uniform. The mask/hood only and gloves only completion times were significantly shorter than those from the MOPP 4 trials. The protective mask/hood and gloves have a definite and approximately equal contribution to any degradation in performance attributed to MOPP 4.

5. Participants performing the Dragon repair task significantly improved their completion times between the first and second presentation of the trials, but not between the second and third presentation of the trials. This was also true when the participants were in the duty uniform. In MOPP 4 the first and third presentations were significantly different. There was no difference in the degree of improvement (attributed to learning) observed when comparing the duty uniform and MOPP 4 conditions.

6. As a result of preliminary investigation at the school, there probably exists any number of tasks which may confront missile repair persons that cannot be performed in MOPP 4 because of physical interference between the protective clothing and the equipment. These could be thoroughly documented by the school.

7. Even though the level of physical effort expended by the participants fell into the category of light work, there was observed evidence of difficulties in areas of heat buildup, perspiration, stress, discomfort, and visual and manual impairment while attired in MOPP 4. In formulating the scenario for this experiment, it was thought that heat buildup concerns had been largely sidestepped. From a medical and safety standpoint, there was no problem; but considering on-the-job performance, it was a factor probably contributing to the observed degradations.

RECOMMENDATIONS

1. This experiment has demonstrated that there is at least one form of activity, procedural and diagnostic work, that apparently does not suffer a significant elapsed time degradation when personnel are attired in MOPP 4. Other types of activity may exist which are also unaffected. Further investigation of the many different types of activities where NBC protective posture is employed certainly appears warranted.

2. Military planners and analysts, including those who develop and draw conclusions from computer models, should pay particular attention to the activities simulated when applying degradation factors for personnel in MOPP 4. In certain cases (as described in the sixth factor, BACKGROUND section), degradation can be total while other activities may be unaffected. Such planners and analysts would find it advantageous to support the continued investigations advocated above.

3. Unit commanders are reminded that the results described and discussed here were derived from trials conducted in controlled conditions and environment. Field conditions are highly variable requiring commanders to take into account all of the physical and psychological factors listed in the BACKGROUND section as they may impact accomplishment of their mission.

4. The equipment presently making up the MOPP 4 ensemble is in considerable need of improvement as even "light work" activities can be affected with the difficulties and discomforts described herein.

REFERENCES

1. Department of the Army. Prevention, treatment and control of heat injury (TB MED 507). Washington, DC: Author, July 1980.

2. Duncan, D. B. Multiple range and multiple F tests Biometrics, March 1955, I-42.

3. Kirk, R. E. "Experimental design: Procedures for the behavioral sciences". California: Brooks/Cole, 1968.

4. Letter to USAHEL from Deputy Chief of Staff for Combat Developments, HQ USA Training and Doctrine Command, subject; Mission Area Analysis (MAA), 27 February 1981.

5. Lindquist, E. F. Design and analysis of experiments in psycholcgy and education. Boston: Houghton Mifflin, 1953.

6. Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., & Bent, D. H. Statistic l package for the social sciences. New York: McGraw-Hill, 1975.

7. Rakaczky, J. A. The effect of chemical protective clothing and equipment on combat efficiency (TR 313). Aberdeen Proving Ground, MD: USA Materiel Systems Analysis Activity, November 1981.

8. Shearin, D. J. Chemical decontamination survivability of selected ammunition electronic components (TM 5-82). Aberdeen Proving Ground, MD: USA Human Engineering Laboratory, March 1982.

9. Snedecor, G. W., & Cochran, W. G. Statistic methods. (6th ed.). Ames, IA: Iowa State University Press, 1967.

APPENDIX A

VOLUNTEER AGREEMENT

VOLUNTEER AGREEMENT

(Military Personnel)

I, ______________________________, having full capacity to consent, do hereby volunteer to participate in a research study entitled: Missile Electronic Repair When Wearing CBR Protective Clothing under the direction of Mr. John D. Waugh, US Army Human Engineering Laboratory.

The implications of my voluntary participation; the nature, duration and purpose; the methods and means by which it is to be conducted, and the inconvenience and hazards which may reasonably be expected have been explained to me by Mr. Waugh, and are set forth on the reverse side of this Agreement, which I have initialed. I have been given an opportunity to ask questions concerning this investigational study, and any such questions have been answered to my full and complete satisfaction.

I understand that I may at any time during the course of this study revoke my consent, and withdraw from the study without prejudice; however, I may be required to undergo certain further examinations, if, in the opinion of the attending physician, such examinations are necessary for my health or well being.

______________________________ Signature ______________ Date

I was present during the explanation referred to above, as well as the volunteer's opportunity for questions, and hereby witness his signature.

______________________________ Witness' Signature ______________ Date

1. Participants will perform missile electronic repair task while wearing various items of CBR protective clothing.

2. Each of the repair task trials will last from approximately one-half hour to two hours depending upon the task. Each repair task will be repeated several times to determine if performance improves with training.

3. Although participation in this study is voluntary, once volunteered, it is considered a duty assignment. Adherence to the duty schedule is expected.

4. The purpose of this investigation is to determine participant's performance as a result of wearing the various combinations of CBR protective clothing.

5. Participants may experience some discomfort and hinderance in performing repair tasks in protective clothing. This is to be expected, however, no toxic agents or even simulated toxic agents will be used in this investigation. There are no risks attached to the investigation.

____
(Initials)

APPENDIX B

COMPLETE LIST OF PROTECTIVE CLOTHING AND EQUIPMENT

COMPLETE LIST OF PROTECTIVE CLOTHING AND EQUIPMENT

Nomenclature	NSN	Size
Bag, barracks, cotton sateen, olive green	8465-00-530-3692	
CB gloves (toxicological agent protective) w/liner	8415-00-753-6550	XS
	8415-00-753-6551	S
	8415-00-753-6552	M
	8415-00-753-6553	L
	8415-00-753-6554	XL
Hood; M6 A2		
Mask, (CBR protective) M17A1		
CB overboots	8415-01-021-5971	
Suit, Cml Protective Overgarment	8415-00-407-1060	X-small
	8415-00-177-5007	small
	8415-00-177-5008	medium
	8415-00-407-1062	large
	8415-00-407-1063	extra-large

APPENDIX C

QUESTIONNAIRE

ELECTRONIC REPAIRPERSON'S POST TRIAL QUESTIONNAIRE
(To be completed immediately after each daily trial)

PART I - (To be completed by HEL staff representative)

Repairperson's Sequence Number ____________________

Task Title ____________________

Sub-Task Title ____________________ Fault Category: E-( ) H-( )

Condition: Duty Uniform ____________________ MOPP Gloves only ______

Mask only ____________________ Full MOPP Ensemble ______

PART II - (To be complete by Repairperson)

PURPOSE The purpose of this questionnaire is to obtain your reaction to each test trial immediately upon completion while your experiences are fresh in your mind. A copy of each of these questionnaires will be returned to you upon completion of the total series of trials to be used by you as an aid when filling out the more detailed POST-TEST QUESTIONNAIRE.

1. List those tools or test equipment (up to a maximum of five) which were difficult to use, starting with the most difficult (5) and finishing with those of lesser difficulty, and explain why. If some tools or equipment were easy to use, do not list them.

Tool/Test Equipment		Reason for Difficulty
	(5)	
	(4)	
	(3)	
	(2)	
	(1)	

2. Of the tasks performed, rate them in terms of least difficult to perform (1) to to most dfficult (5)

( ) Disassemble ( ) Repair/Replace Components ( ) Reassemble
( ) Diagnose ( ) Perform Checks

3. Was it difficult to pick up small objects: ( ) Yes ( ) No

4. Was it difficult to see small objects: ( ) Yes ( ) No

5. Was it difficult to work with the maintenance manual ( ) Yes ( ) NO

6. How do you feel about the quality of your work on this task?

I felt my performance was (check one below):

Excellent						Very Poor
	1	2	3	4	5	